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(54) **A human flavin-containing monooxygenase**

(57) A flavin-containing monooxygenase comprising an amino acid sequence set out in SEQ ID NO:7, a microorganism producing said flavin-containing monooxygenase, a flavin-containing monooxygenase gene containing a DNA sequence coding for the amino acid sequence set out in SEQ ID NO:7, a flavin-containing monooxygenase gene containing a DNA sequence set out in SEQ ID NO:7, a plasmid containing said flavin-containing monooxygenase gene, a microorganism containing said plasmid, and a method for producing the enzyme of the present invention wherein said microorganism is cultured to produce the enzyme.

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## Description

The present invention relates to a novel human flavin-containing monooxygenase (FMO) gene.

Flavin-containing monooxygenases of rat, pig and rabbit have been known as microsomal xenobiotic-metabolizing enzymes which oxidize various xenobiotics including drugs, agricultural chemicals and environmental pollutants incorporated into bodies, and it has also been known that they have a plurality of isozymes. Therefore, precise characterization and specific function of each enzyme molecule have not been thoroughly understood. Particularly, with regard to human flavin-containing monooxygenases, only 3 human flavin-containing monooxygenases have been elucidated by cloning of cDNA (Dolphin et al., J. Biol. Chem., 266, 12379-12385, (1991), Dolphin et al., Biochem. J., 287, 261-267 (1992), Lomri et al. Proc. Natl. Acad. Sci. 89, 1685-1689 (1992)). Therefore, many aspects of human flavin-containing monooxygenases, such as population distribution of the isozymes in human and their function to metabolize or detoxify xenobiotics, remain unknown.

To solve this problem, the present inventors have found a novel human flavin-containing monooxygenase and produced in a large quantity a functional human flavin-containing monooxygenase by a DNA amplification technique using particular oligonucleotides as primers and a genetic engineering method.

Thus, the present invention provides nucleotide sequences encoding a human flavin-containing monooxygenase, wherein these nucleotide sequences are RNA and DNA sequences, such as a flavin-containing monooxygenase gene containing a DNA sequence coding for the amino acid sequence set out in SEQ ID NO:7,

a flavin-containing monooxygenase gene containing a DNA sequence as set out in SEQ ID NO:7 (hereinafter, referred to as the gene of the invention),

a vector containing said flavin-containing monooxygenase gene (hereinafter, referred to as the vector of the invention), a host cell containing said vector, and a method for producing the enzyme of the present invention, which comprises culturing said host cell and recovering the enzyme it produces.

The host cell of the invention includes, but is not limited to, microorganisms such as yeast. The vector of the invention includes, but is not limited to, plasmid and phage vectors, such as a plasmid suitable for expression in yeast. The present invention also provides nucleotide sequences that hybridize to the above-mentioned nucleotide sequences and that encode an enzyme having the xenobiotic-oxidizing activity of human flavin-containing monooxygenase. In this context, the term "hybridization" refers to conventional hybridization conditions and preferably to stringent hybridization conditions. The present invention also provides an enzyme encoded by any one of the above-mentioned nucleotide sequences or produced by the above method.

The present invention further provides an antibody, preferably monoclonal, which specifically binds to an epitope of the enzyme of the invention. The present invention further provides an oligonucleotide probe which specifically binds the nucleotide sequence of the invention.

The present invention additionally provides a cell-free extract, preferably a microsomal fraction, prepared from the host cell of the invention. The present invention further provides a method for metabolizing a sample compound comprising preparing a mixture of the sample compound and the host cell or cell-free extract of the invention, incubating the mixture and, optionally analyzing the metabolite so produced.

The above and other objects, features, and advantages of the present invention will be better understood from the following detailed descriptions taken in conjunction with the accompanying drawing, which is given by way of illustration only and is not limitative of the present invention, in which:

Figure 1 shows a construction method of a yeast expression plasmid (pAFMO) for a human flavin-containing monooxygenase.

The present invention provides a novel human flavin-containing monooxygenase, a host cell which produces said enzyme, a nucleotide sequence comprising said enzyme gene and nucleotide sequences hybridizing therewith, and a vector containing said nucleotide sequence. The expressed enzyme of the present invention is useful to evaluate human xenobiotic metabolism in vitro.

The invention will be described in detail as follows:

The enzyme of the present invention is novel, and differs from any of the aforementioned three known human flavin-containing monooxygenases. Its amino acid sequence or the DNA sequence coding for said sequence has about 50 to 95% homology with those of the amino acid sequences or DNA sequences of the aforementioned known enzymes, respectively.

The gene of the present invention can be prepared by a conventional genetic engineering method, for example, which comprises cloning subject gene prepared from a cDNA library. The cDNA library can be obtained by the steps of: Preparing an mRNA fraction of said gene, producing cDNA using reverse transcriptase, and inserting said cDNA into a vector, preferably a phage vector or a plasmid vector. Alternatively, a commercially available cDNA library derived from human liver may be screened using either (i) a DNA fragment which exhibits homology with the gene or (ii) an antibody

which recognizes the protein produced by the gene. Furthermore, the gene can be prepared by cloning the subject gene from the cDNA library described above by PCR using a specific oligonucleotide as a primer.

A specific oligonucleotide to be used as a primer in PCR includes, for example, DNA fragments as set forth in SEQ ID NO:1 to 4. When said primers are used, about 1.6 Kb fragment corresponding to the protein coding region of human flavin-containing monooxygenase gene excluding 60 bp of N-terminal can be amplified separately as two fragments of about 0.8 Kb and about 1.0 Kb. The resulting two fragments, about 0.8 Kb and about 1.0 Kb, and the fragment corresponding to the N-terminal of about 60 bp (linker) are ligated by a conventional genetic engineering method, thus the preparation of the gene of the present invention is accomplished.

The vector of the present invention is usually constructed by inserting the gene of the present invention into an expression vector. The expression vector usually must contain genetic information that can be replicated in host cells, propagate independently, be readily isolated and purified from the host cells and further contain a detectable marker. Such a vector can be constructed by a conventional genetic engineering method.

In a yeast expression system, for example, a yeast expression plasmid can be prepared by inserting the gene of the present invention obtained by cloning into an expression vector containing a promoter and terminator which are functional in yeast.

A functional promoter in yeast to be used in the invention includes, e.g., the promoters of a yeast alcohol dehydrogenase gene (hereinafter, referred to as ADH promoter), a glyceraldehyde-3-phosphate dehydrogenase gene (hereinafter, referred to as GAPDH promoter), and a phosphoglycerate kinase gene (hereinafter, referred to as PGK promoter).

The ADH promoter can be prepared, for example, from the yeast expression vector pAAH5 containing yeast ADH1 promoter and terminator (available from Washington Research Foundation, Ammerer et al. Methods in Enzymology, 101, p192-201) by a conventional genetic engineering method. Since the yeast ADH1 promoter is disclosed by U.S. Pat. No. 299,733 (1981/9/31) of Washington Research Foundation, industrial or commercial use of the the promoter requires approval of the patentee. Said yeast expression plasmid containing the aforementioned promoter and terminator which exert their functions in yeast, and human flavin-containing monooxygenase gene can be readily constructed by a conventional genetic engineering method. For example, the plasmid can be constructed by inserting the human flavin-containing monooxygenase gene into the HindIII sites of the yeast expression vector pAAH5N containing the ADH promoter and ADH terminator disclosed in JP-A No.21180/1990.

The resulting vector of the present invention is introduced into a host cell by a conventional method to produce the transformant host cell. Then, said host cell is cultured to produce the enzyme of the present invention selectively and in a large quantity.

For example, the vector of the present invention is introduced into yeast such as *Saccharomyces cerevisiae* according to a method such as an alkali metal (LiCl) method. The yeast into which said vector is introduced is then cultured to produce the enzyme of the present invention by a conventional method.

The expressed enzyme is localized in the microsomal membrane and exerts its monooxygenase activity. Therefore, the expressed enzyme can, for example, be used to investigate metabolism of a xenobiotic in vitro and is preferably used in a form of intact yeast cells or cell-free extracts. A cell-free extract includes, for example, a microsomal fraction. The preparation of the cell-free extracts or the microsomal fraction may be performed according to a conventional method described, for example, in DNA, vol. 4. No.3, page 203 - page 210 (1985).

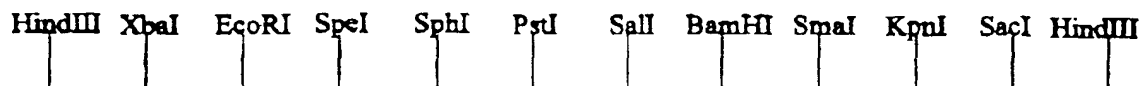
The yeast cells or the cell-free extracts thus obtained may be used to analyze a metabolic pathway of a sample compound by reacting the sample compound with the yeast cells or the cell-free extracts. The reaction can be performed by adding the sample compound to a culture of the the yeast cells or a solution of cell-free extracts such as culture medium or buffer containing the yeast cells or the cell-free extracts, and by incubating the reaction mixture, for example, at a temperature of about 10 to 40°C, for about 0.1 to 48 hours. The amount of the yeast cells or said cell-free extracts and the amount of the sample compound to be added to the reaction mixture may be varied according to various conditions such as the reaction temperature, reaction time and the type of the sample compound. For example, the amount of the yeast cells or said cell-free extracts is preferably between about  $10^7$  and about  $10^8$  cells or about 5 to 200  $\mu$ l of the microsomal fraction (per 1 ml of the solution) and the amount of the sample compound to be added to the reaction mixture is preferably between about 0.01 and 1  $\mu$ mole per 1 ml of the solution. These amounts can be optionally increased or decreased irrespective of a limitation of the above-described ranges.

After completion of the reaction, analysis of metabolites in the reaction solution can be conducted according to a conventional analytical method described in Guideline of Instrumental Analysis (2) (New edition first published 1985), KAGAKU-DOJIN Publishing Company edited by Jiro Shiokawa et al, or Spectrometric Identification of Organic compounds (Fourth edition third published 1984), TOKYO KAGAKU DOJIN Co., Ltd. Publishers edited by R. M. Silver et al.. On the basis of the analytical data above, it can be judged as to whether the sample compound is either detoxified to a metabolite or activated to a carcinogen by the present enzyme.

The invention will be further illustrated with reference to the following examples; however, these examples are not to be construed to limit the scope of the invention.

**EXAMPLE 1: METHOD FOR OBTAINING THE GENE**

Using the primers set out in SEQ ID NO:1 to 4, about 1.6 Kb fragment corresponding to the protein coding region of human flavin-containing monooxygenase gene without 60 bp of N-terminals was amplified separately as two fragments: about 0.8 Kb and about 1.0 Kb, according to PCR. One of the amplified fragments of about 0.8 Kb was cleaved with *SacI* and subcloned into the *SmaI-SacI*-site of the pUC A vector, which was prepared by modifying the *EcoRI* site of pUC19 (TAKARA SHUZO) into the *HindIII* site, and by converting the cloning sites between the *HindIII* sites into the following cloning sites:



The obtained subclone was treated with *SacI*, and ligated to the fragment of about 1.0 Kb which was pretreated with *SacI*, and then, the resulting plasmid was further treated with *XbaI* and *XhoI* into which the linkers set out in SEQ ID NO:5 and 6 were inserted (see Figure 1). The gene corresponding to the protein coding region of human flavin-containing monooxygenase was sequenced using a fluorescence DNA sequencer (model 373A, Applied Biosystems) which is based on the dideoxy method. The result is shown in SEQ ID NO:7, accompanied by the deduced amino acid sequence.

**EXAMPLE 2: CONSTRUCTION OF THE PLASMID**

The gene corresponding to the protein coding region of human flavin-containing monooxygenase was prepared by cleaving the obtained plasmid with *HindIII*, and inserted into pAAH5N, whereby the yeast expression plasmid pAFMO was constructed, which allowed the gene of the invention to express in yeast (see Figure 1).

**EXAMPLE 3: PRODUCTION OF THE MICROORGANISM**

*Saccharomyces cerevisiae* AH22 was inoculated in 1 ml of YPD medium (1%(w/v) yeast extract, 2%(w/v) polypeptone, and 2%(w/v) glucose), cultivated at 30°C for 18 hours, and then collected by centrifugation (10,000 x g, 2 minutes, room temperature). The obtained cells were suspended in 1 ml of 0.2 M LiCl solution, then centrifuged again, and to the resulting pellet were added 20 µl of 1 M LiCl, 30 µl of 70%(w/v) polyethyleneglycol 4000 solution and 10 µl of the solution containing about 1.0 µg of the plasmid of the present invention (pAFMO) constructed in Example 2. The resulting solution was thoroughly mixed, then incubated at 30°C for 1 hour, further added to 140 µl of distilled water, and stirred. The solution was spread on the SD synthetic plate (2.0%(w/v) glucose, 0.67%(w/v) yeast nitrogen base without amino acid, 20 g/ml Histidine, 2.0%(w/v) agar), incubated at 30°C for 3 days, and the transformant containing the plasmid of the present invention (pAFMO) was obtained.

**EXAMPLE 4: PREPARATION OF THE MICROSOMAL FRACTION OF YEAST**

The microorganism of the present invention (a transformed yeast produced in Example 3) was collected from 3.8 liter of the liquid medium in which the microorganism was cultured up to about  $1.0 \times 10^8$  cells/ml. The yeast cells were suspended in 400 ml of buffer A (10 mM Tris-HCl (pH7.5), 2 M sorbitol, 0.1 mM DTT, 0.2 mM EDTA), and to the resulting solution was added 160 mg of Zymolyase 100T, and incubated at 30 °C for 60 minutes. After suspending spheroplasts obtained by centrifugation (5,000 x g, 10 minutes, 4°C) in 100 ml of buffer A, the resulting solution was subjected to centrifugation (5,000 x g, 10 minutes, 4°C). After washing the spheroplasts by subjecting the solution to centrifugation again under the same conditions, the spheroplasts were suspended in 200 ml of the buffer (10 mM Tris-HCl (pH7.5), 0.65 M sorbitol, 0.1 mM DTT), and disrupted by ultrasonication (50 W, 5 minutes, 0°C). The supernatant obtained by centrifugation (9,000 x g, 20 minutes, 4°C) is referred to as yeast S-9 Mix fraction hereinafter. This fraction was further centrifuged (125,000 x g, 70 minutes, 4°C) to collect pellets, which were then suspended in 10 ml of 0.1 M phosphate buffer (pH7.4) to obtain a microsomal fraction.

**EXAMPLE 5: ASSAY OF THIOUREA S-OXYGENASE ACTIVITY IN THE MICROSOMAL FRACTION OF YEAST WHICH EXPRESSES THE ENZYME**

5 The reaction was initiated by adding 200  $\mu$ l of the microsomal fraction prepared in Example 4 and 25  $\mu$ l of 120 mM thiourea to 2.5 ml of an assay solution (0.1 M potassium phosphate buffer, pH7.5, 0.2 mM NADPH, 160  $\mu$ M thiocholine, 100 units catalase, 2 mM benzylimidazole, 0.4 mM EDTA) previously warmed at 37°C. 400  $\mu$ l of the mixture was added to 40  $\mu$ l of 3 M TCA every 3 minutes, the resulting mixture was left standing on ice, and then centrifuged to obtain 350  $\mu$ l of a supernatant. To the supernatant were added 1 ml of 1 M potassium phosphate buffer (pH7.5), 0.6 ml of water and 50  $\mu$ l of 10 mM dithiobisnitrobenzoic acid for coloration, and decrease of thiocholine was measured with an absorption at 412 nm. Thiourea S-oxygenase activity was found in the yeast microsomal fraction expressing the present enzyme.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

(A) NAME: Sumitomo Chemical Company, Limited  
 (B) STREET: 5-33, Kitahama 4-chome, Kita-ku  
 (C) CITY: Osaka-shi, Osaka  
 (E) COUNTRY: Japan  
 (F) POSTAL CODE (ZIP): none

(ii) TITLE OF INVENTION: A human flavin-containing monooxygenase

(iii) NUMBER OF SEQUENCES: 8

(iv) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk  
 (B) COMPUTER: IBM PC compatible  
 (C) OPERATING SYSTEM: PC-DOS/MS-DOS  
 (D) SOFTWARE: PatentIn Release #1.0, Version #1.30 (EPO)

(vi) PRIOR APPLICATION DATA:

(A) APPLICATION NUMBER: JP 06-284902  
 (B) FILING DATE: 18-NOV-1994

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 31 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

(A) DESCRIPTION: /desc = "synthetic DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

GTCTCGAGGA AGGACTGGAG CCCACCTGCT T

31

(2) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 31 base pairs  
 (B) TYPE: nucleic acid  
 (C) STRANDEDNESS: single  
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

(A) DESCRIPTION: /desc = "synthetic DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

5 GCCACACAGA ATGCTTGCTG GGAGCTCATC A 31

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

- 10 (A) LENGTH: 31 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- 15 (A) DESCRIPTION: /desc = "synthetic DNA"

20 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

GTGCTCGTC ACTCGATTTG GAACCTTCCT C 31

25 (2) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

- 30 (A) LENGTH: 31 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- 35 (A) DESCRIPTION: /desc = "synthetic DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

40 AAGAGCTCAG CCCCTGTCTG GGTATTGTCA G 31

(2) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:

- 45 (A) LENGTH: 69 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

50 (ii) MOLECULE TYPE: other nucleic acid

- 55 (A) DESCRIPTION: /desc = "synthetic DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

CTAGAATGGG GAAGAAAGTG GCCATCATTG GAGCTGGTGT GAGTGGCTTG GCCTCCATCA 60  
GGAGCTGTC 69

(2) INFORMATION FOR SEQ ID NO: 6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 69 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "synthetic DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

TTACCCCTTC TTTCACCGGT AGTAACCTCG ACCACACTCA CCGAACCGGA GGTAGTCCTC 60  
GACAGAGCT 69

(2) INFORMATION FOR SEQ ID NO: 7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1599 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION:1..1596

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

ATG GGG AAG AAA GTG GCC ATC ATT GGA GCT GGT GTG AGT GGC TTG GCC 48  
Met Gly Lys Lys Val Ala Ile Ile Gly Ala Gly Val Ser Gly Leu Ala  
1 5 10 15  
TCC ATC AGG AGC TGT CTC GAG GAA GGA CTG GAG CCC ACC TGC TTT GAG 96  
Ser Ile Arg Ser Cys Leu Glu Glu Gly Leu Glu Pro Thr Cys Phe Glu  
20 25 30



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5	AAG AGC AAT GAC ATT GGG GGC CTG TGG AAA TTT TCA GAC CAT GCA GAG Lys Ser Asn Asp Ile Gly Gly Leu Trp Lys Phe Ser Asp His Ala Glu	144
	35 40 45	
10	GAG GGC AGG GCT AGC ATT TAC AAA TCA GTC TTT TCC AAC TCT TCC AAA Glu Gly Arg Ala Ser Ile Tyr Lys Ser Val Phe Ser Asn Ser Ser Lys	192
	50 55 60	
15	GAG ATG ATG TGT TTC CCA GAC TTC CCA TTT CCC GAT GAC TTC CCC AAC Glu Met Met Cys Phe Pro Asp Phe Pro Phe Pro Asp Asp Phe Pro Asn	240
	65 70 75 80	
20	TTT ATG CAC AAC AGC AAG ATC CAG GAA TAT ATC ATT GCA TTT GCC AAA Phe Met His Asn Ser Lys Ile Gln Glu Tyr Ile Ile Ala Phe Ala Lys	288
	85 90 95	
25	GAA AAG AAC CTC CTG AAG TAC ATA CAA TTT AAG ACA TTT GTA TCC AGT Glu Lys Asn Leu Leu Lys Tyr Ile Gln Phe Lys Thr Phe Val Ser Ser	336
	100 105 110	
30	GTA AAT AAA CAT CCT GAT TTT GCA ACT ACT GGC CAG TGG GAT GTT ACC Val Asn Lys His Pro Asp Phe Ala Thr Thr Gly Gln Trp Asp Val Thr	384
	115 120 125	
35	ACT GAA AGG GAT GGT AAA AAA GAA TCG GCT GTC TTT GAT GCT GTA ATG Thr Glu Arg Asp Gly Lys Lys Glu Ser Ala Val Phe Asp Ala Val Met	432
	130 135 140	
40	GTT TGT TCT GGA CAT CAT GTG TAT CCC AAC CTA CCA AAA GAG TCC TTT Val Cys Ser Gly His His Val Tyr Pro Asn Leu Pro Lys Glu Ser Phe	480
	145 150 155 160	
45	CCA GGA CTA AAC CAC TTT AAA GGC AAA TGC TTC CAC AGC AGG GAC TAT Pro Gly Leu Asn His Phe Lys Gly Lys Cys Phe His Ser Arg Asp Tyr	528
	165 170 175	
50	AAA GAA CCA GGT GTA TTC AAT GGA AAG CGT GTC CTG GTG GTT GGC CTG Lys Glu Pro Gly Val Phe Asn Gly Lys Arg Val Leu Val Val Gly Leu	576
	180 185 190	
55	GGG AAT TCG GGC TGT GAT ATT GCC ACA GAA CTC AGC CGC ACA GCA GAA Gly Asn Ser Gly Cys Asp Ile Ala Thr Glu Leu Ser Arg Thr Ala Glu	624
	195 200 205	
60	CAG GTC ATG ATC AGT TCC AGA AGT GGC TCC TGG GTG ATG AGC CGG GTC Gln Val Met Ile Ser Ser Arg Ser Gly Ser Trp Val Met Ser Arg Val	672
	210 215 220	
65	TGG GAC AAT GGT TAT CCT TGG GAC ATG TTG CTC GTC ACT CGA TTT GGA Trp Asp Asn Gly Tyr Pro Trp Asp Met Leu Leu Val Thr Arg Phe Gly	720
	225 230 235 240	
70	ACC TTC CTC AAG AAC AAT TTA CCG ACA GCC ATC TCT GAC TGG TTG TAC Thr Phe Leu Lys Asn Asn Leu Pro Thr Ala Ile Ser Asp Trp Leu Tyr	768
	245 250 255	

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5	GTG AAG CAG ATG AAT GCA AGA TTC AAG CAT GAA AAC TAT GGC TTG ATG Val Lys Gln Met Ala Arg Phe Lys His Glu Asn Tyr Gly Leu Met	816
	260 265 270	
10	CCT TTA AAT GGA GTC CTG AGG AAA GAG CCT GTA TTT AAT GAT GAG CTC Pro Leu Asn Gly Val Leu Arg Lys Glu Pro Val Phe Asn Asp Glu Leu	864
	275 280 285	
15	CCA GCA AGC ATT CTG TGT GGC ATT GTG ACC GTA AAG CCT AAC GTG AAG Pro Ala Ser Ile Leu Cys Gly Ile Val Thr Val Lys Pro Asn Val Lys	912
	290 295 300	
20	GAA TTC ACA GAG ACC TCG GCC ATT TTT GAG GAT GGG ACC ATA TTT GAG Glu Phe Thr Glu Thr Ser Ala Ile Phe Glu Asp Gly Thr Ile Phe Glu	960
	305 310 315 320	
25	GGC ATT GAC TGT GTA ATC TTT GCA ACA GGG TAT AGT TTT GCC TAC CCC Gly Ile Asp Cys Val Ile Phe Ala Thr Gly Tyr Ser Phe Ala Tyr Pro	1008
	325 330 335	
30	TTC CTT GAT GAG TCT ATC ATC AAA AGC AGA AAC AAT GAG ATC ATT TTA Phe Leu Asp Glu Ser Ile Ile Lys Ser Arg Asn Asn Glu Ile Ile Leu	1056
	340 345 350	
35	TTT AAA GGA GTA TTT CCT CCT CTA CTT GAG AAG TCA ACC ATA GCA GTG Phe Lys Gly Val Phe Pro Pro Leu Leu Glu Lys Ser Thr Ile Ala Val	1104
	355 360 365	
40	ATT GGC TTT GTC CAG TCC CTT GGG GCT GCC ATT CCC ACA GTT GAC CTC Ile Gly Phe Val Gln Ser Leu Gly Ala Ala Ile Pro Thr Val Asp Leu	1152
	370 375 380	
45	CAG TCC CGC TGG GCA GCA CAA GTA ATA AAG GGA ACT TGT ACT TTG CCT Gln Ser Arg Trp Ala Ala Gln Val Ile Lys Gly Thr Cys Thr Leu Pro	1200
	385 390 395 400	
50	TCT ATG GAA GAC ATG ATG AAT GAT ATT AAT GAG AAA ATG GAG AAA AAG Ser Met Glu Asp Met Met Asn Asp Ile Asn Glu Lys Met Glu Lys Lys	1248
	405 410 415	
55	CGC AAA TGG TTT GGC AAA AGC GAG ACC ATA CAG ACA GAT TAC ATT GTT Arg Lys Trp Phe Gly Lys Ser Glu Thr Ile Gln Thr Asp Tyr Ile Val	1296
	420 425 430	
60	TAT ATG GAT GAA CTC TCC TCC TTC ATT GGG GCA AAG CCC AAC ATC CCA Tyr Met Asp Glu Leu Ser Ser Phe Ile Gly Ala Lys Pro Asn Ile Pro	1344
	435 440 445	
65	TGG CTG TTT CTC ACA GAT CCC AAA TTG GCC ATG GAA GTT TAT TTT GGC Trp Leu Phe Leu Thr Asp Pro Lys Leu Ala Met Glu Val Tyr Phe Gly	1392
	450 455 460	

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5 CCT TGT AGT CCC TAC CAG TTT AGG CTG GTG GGC CCA GGG CAG TGG CCA 1440  
Pro Cys Ser Pro Tyr Gln Phe Arg Leu Val Gly Pro Gly Gln Trp Pro  
465 470 475 480

GGA GCC AGA AAT GCC ATA CTG ACC CAG TGG GAC CGG TCG TTG AAA CCC 1488  
Gly Ala Arg Asn Ala Ile Leu Thr Gln Trp Asp Arg Ser Leu Lys Pro  
485 490 495

10 ATG CAG ACA CGA GTG GTC GGG AGA CTT CAG AAG CCT TGC TTC TTT TTC 1536  
Met Gln Thr Arg Val Val Gly Arg Leu Gln Lys Pro Cys Phe Phe Phe  
500 505 510

15 CAT TGG CTG AAG CTC TTT GCA ATT CCT ATT CTG TTA ATC GCT GTT TTC 1584  
His Trp Leu Lys Leu Phe Ala Ile Pro Ile Leu Leu Ile Ala Val Phe  
515 520 525

20 CTT GTG TTG ACC TAA 1599  
Leu Val Leu Thr  
530

## (2) INFORMATION FOR SEQ ID NO: 8:

25 (i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 532 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

30 (ii) MOLECULE TYPE: protein  
(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

Met Gly Lys Lys Val Ala Ile Ile Gly Ala Gly Val Ser Gly Leu Ala  
1 5 10 15

35 Ser Ile Arg Ser Cys Leu Glu Glu Gly Leu Glu Pro Thr Cys Phe Glu  
20 25 30

Lys Ser Asn Asp Ile Gly Gly Leu Trp Lys Phe Ser Asp His Ala Glu  
35 40 45

40 Glu Gly Arg Ala Ser Ile Tyr Lys Ser Val Phe Ser Asn Ser Ser Lys  
50 55 60

45 Glu Met Met Cys Phe Pro Asp Phe Pro Phe Pro Asp Asp Phe Pro Asn  
65 70 75 80

Phe Met His Asn Ser Lys Ile Gln Glu Tyr Ile Ile Ala Phe Ala Lys  
85 90 95

50 Glu Lys Asn Leu Leu Lys Tyr Ile Gln Phe Lys Thr Phe Val Ser Ser  
100 105 110

Val Asn Lys His Pro Asp Phe Ala Thr Thr Gly Gln Trp Asp Val Thr  
115 120 125

55

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5 Thr Glu Arg Asp Gly Lys Lys Glu Ser Ala Val Phe Asp Ala Val Met  
130 135 140

Val Cys Ser Gly His His Val Tyr Pro Asn Leu Pro Lys Glu Ser Phe  
145 150 155 160

10 Pro Gly Leu Asn His Phe Lys Gly Lys Cys Phe His Ser Arg Asp Tyr  
165 170 175

Lys Glu Pro Gly Val Phe Asn Gly Lys Arg Val Leu Val Val Gly Leu  
180 185 190

15 Gly Asn Ser Gly Cys Asp Ile Ala Thr Glu Leu Ser Arg Thr Ala Glu  
195 200 205

Gln Val Met Ile Ser Ser Arg Ser Gly Ser Trp Val Met Ser Arg Val  
210 215 220

20 Trp Asp Asn Gly Tyr Pro Trp Asp Met Leu Leu Val Thr Arg Phe Gly  
225 230 235 240

Thr Phe Leu Lys Asn Asn Leu Pro Thr Ala Ile Ser Asp Trp Leu Tyr  
245 250 255

25 Val Lys Gln Met Asn Ala Arg Phe Lys His Glu Asn Tyr Gly Leu Met  
260 265 270

Pro Leu Asn Gly Val Leu Arg Lys Glu Pro Val Phe Asn Asp Glu Leu  
275 280 285

Pro Ala Ser Ile Leu Cys Gly Ile Val Thr Val Lys Pro Asn Val Lys  
290 295 300

35 Glu Phe Thr Glu Thr Ser Ala Ile Phe Glu Asp Gly Thr Ile Phe Glu  
305 310 315 320

Gly Ile Asp Cys Val Ile Phe Ala Thr Gly Tyr Ser Phe Ala Tyr Pro  
325 330 335

40 Phe Leu Asp Glu Ser Ile Ile Lys Ser Arg Asn Asn Glu Ile Ile Leu  
340 345 350

Phe Lys Gly Val Phe Pro Pro Leu Leu Glu Lys Ser Thr Ile Ala Val  
355 360 365

45 Ile Gly Phe Val Gln Ser Leu Gly Ala Ala Ile Pro Thr Val Asp Leu  
370 375 380

Gln Ser Arg Trp Ala Ala Gln Val Ile Lys Gly Thr Cys Thr Leu Pro  
385 390 395 400

Ser Met Glu Asp Met Met Asn Asp Ile Asn Glu Lys Met Glu Lys Lys  
405 410 415

5 Arg Lys Trp Phe Gly Lys Ser Glu Thr Ile Gln Thr Asp Tyr Ile Val  
420 425 430

Tyr Met Asp Glu Leu Ser Ser Phe Ile Gly Ala Lys Pro Asn Ile Pro  
435 440 445

10 Trp Leu Phe Leu Thr Asp Pro Lys Leu Ala Met Glu Val Tyr Phe Gly  
450 455 460

Pro Cys Ser Pro Tyr Gln Phe Arg Leu Val Gly Pro Gly Gln Trp Pro  
465 470 475 480

15 Gly Ala Arg Asn Ala Ile Leu Thr Gln Trp Asp Arg Ser Leu Lys Pro  
485 490 495

Met Gln Thr Arg Val Val Gly Arg Leu Gln Lys Pro Cys Phe Phe Phe  
20 500 505 510

His Trp Leu Lys Leu Phe Ala Ile Pro Ile Leu Leu Ile Ala Val Phe  
515 520 525

25 Leu Val Leu Thr  
530

### Claims

1. A nucleotide sequence encoding an enzyme having the xenobiotic oxidizing activity of human flavin-containing monooxygenase comprising:
  - (a) a nucleotide sequence as set out in SEQ ID NO:7;
  - (b) a nucleotide sequence coding for the amino acid sequence set out in SEQ ID NO:7; or
  - (c) a nucleotide sequence which hybridizes with (a) or (b).
2. The nucleotide sequence of claim 1 which is DNA.
3. The nucleotide sequence of claim 1 which is RNA.
4. A vector comprising the nucleotide sequence of any one of claims 1 to 3.
5. The vector of claim 4 which is a plasmid or a phage vector.
6. The vector of claim 4 or 5 wherein said nucleotide sequence is operably linked to an expression control sequence.
7. A host cell containing the vector of any one of claims 4 to 6.
8. The host cell of claim 7 which is a yeast cell.
9. A method for producing an enzyme having the xenobiotic oxidizing activity of human flavin-containing monooxygenase, comprising:
  - (a) culturing the host cell of claim 7 or 8; and
  - (b) recovering the enzyme so produced.

10. An enzyme having the xenobiotic oxidizing activity of human flavin-containing monooxygenase and encoded by the nucleotide sequence of any one of claims 1 to 3 or produced by the method of claim 9.

11. An antibody which specifically binds to an epitope of the enzyme of claim 10.

12. The antibody of claim 11 which is a monoclonal antibody.

13. An oligonucleotide probe which specifically binds the nucleotide sequence of any one of claims 1 to 3.

14. A cell-free extract prepared from the host cell of claim 7 or 8.

15. The cell free extract of claim 14 which is a microsomal fraction.

16. A method for metabolizing a sample compound, comprising;

(a) preparing a mixture of the sample compound and the host cell of claim 7 or 8 or the cell-free extract of claim 14 or 15;

(b) incubating the mixture of (a); and, optionally,

(c) analyzing the metabolite so produced.

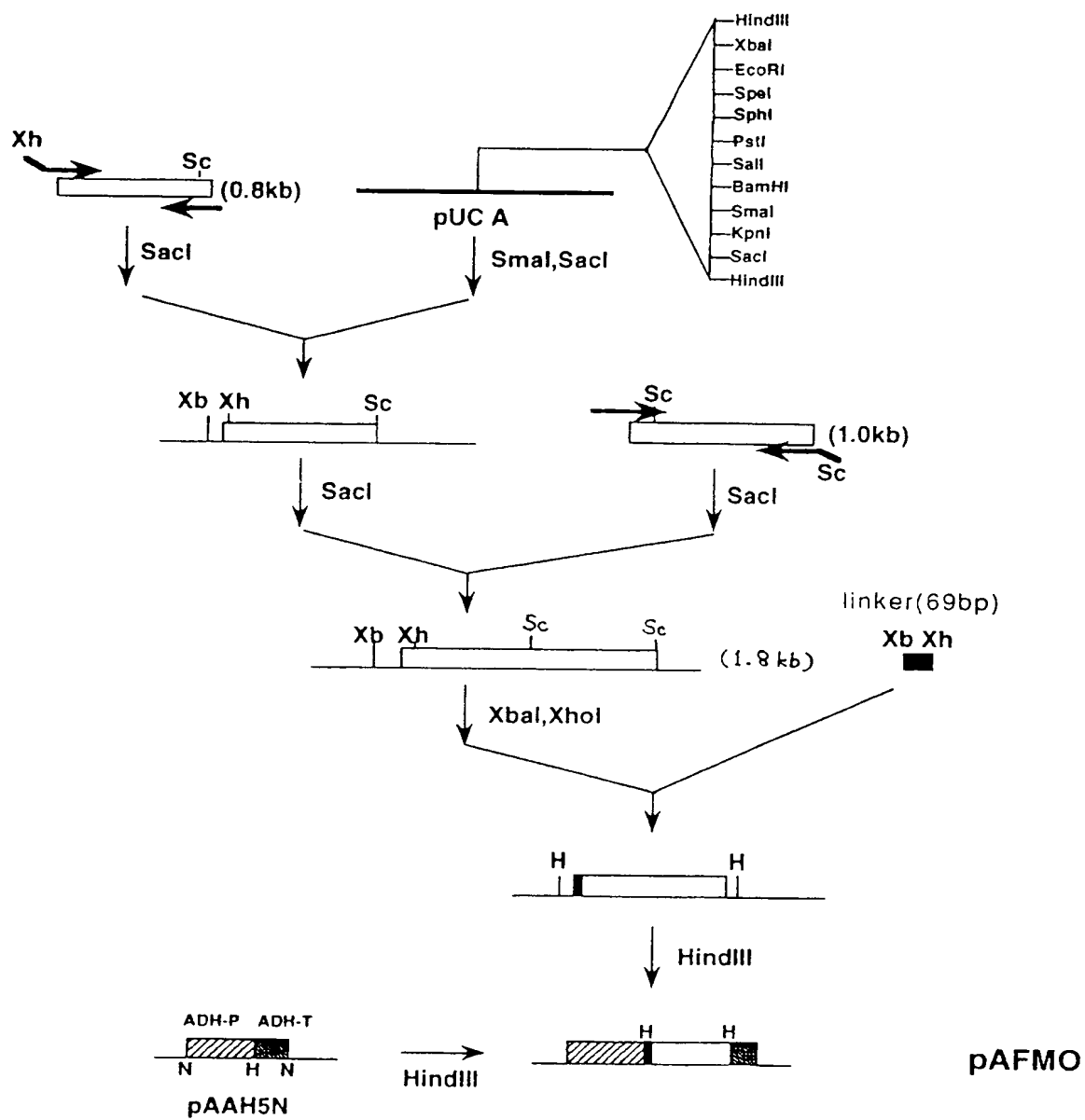


Fig.1





(19)



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**(54) A human flavin-containing monooxygenase**

(57) A flavin-containing monooxygenase comprising an amino acid sequence set out in SEQ ID NO:7, a microorganism producing said flavin-containing monooxygenase, a flavin-containing monooxygenase gene containing a DNA sequence coding for the amino acid sequence set out in SEQ ID NO:7, a flavin-containing monooxygenase gene containing a DNA sequence set out in SEQ ID NO:7, a plasmid containing said flavin-containing monooxygenase gene, a microorganism containing said plasmid, and a method for producing the enzyme of the present invention wherein said microorganism is cultured to produce the enzyme.

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# EUROPEAN SEARCH REPORT

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EP 95 11 8149

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	LOMRI N ET AL: "Molecular cloning of the flavin-containing monooxygenase (form II) cDNA from adult human liver." PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA, (1992 MAR 1) 89 (5) 1685-9. JOURNAL CODE: PV3. ISSN: 0027-8424., XP002043321	1-7,9, 10,13	C12N15/53 C12N9/02 C12N1/19 C12N15/81 C07K16/40 C12Q1/68
Y	* page 1685 - page 1688; figures 1-3 *	4-8	
X	LOMRI N ET AL.: "Expression in Escherichia coli of the flavin-containing monooxygenase D (form II) from adult human liver: determination of a distinct tertiary amine substrate specificity" CHEM. RES. TOXICOL. (JULY/AUGUST 1993), vol. 6, no. 4, pages 425-429, XP002044643 * page 426 - page 427; figure 1; tables I,II *	1-7,9, 10,13-16	
P,X	DOLPHIN C T ET AL: "Differential developmental and tissue-specific regulation of expression of the genes encoding three members of the flavin-containing monooxygenase family of man, FM01, FM03 and FM04." EUROPEAN JOURNAL OF BIOCHEMISTRY 235 (3). 1996. 683-689. ISSN: 0014-2956, XP002043327 * the whole document *	1-7,13	TECHNICAL FIELDS SEARCHED (Int.Cl.6)  C12N C12Q C07K
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		-/--	
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>27 October 1997</b>	Examiner <b>Oderwald, H</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	LOMRI N ET AL: "Regio- and stereoselective oxygenations by adult human liver flavin -containing monooxygenase 3. Comparison with forms 1 and 2." CHEMICAL RESEARCH IN TOXICOLOGY, (1993 NOV-DEC) 6 (6) 800-7. JOURNAL CODE: A5X. ISSN: 0893-228X., XP002043325 * page 800 - page 804; figure 1; tables I-IV *	14-16	
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A	--- LAWTON M P ET AL: "A nomenclature for the mammalian flavin-containing monooxygenase gene family based on amino acid sequence identities." ARCHIVES OF BIOCHEMISTRY AND BIOPHYSICS 308 (1). 1994. 254-257. ISSN: 0003-9861, XP002043326 * the whole document *	1-10,13	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 27 October 1997	Examiner Oderwald, H
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ..... &amp; : member of the same patent family, corresponding document</p>			

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